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Bolko von Rodern
National Center for Photovoltaics
National Renewable Energy Laboratory
1617 Cole Boulevard
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RE: Quarterly Report XII (Nov 2007 - Jan 2008)
"Characterization and Analysis of CIS and CdTe Cells"
Subcontract XXL-5-44205-03

For additional information: www.physics.colostate.edu/groups/photovoltaic

Dear Bolko,

During the past quarter, we continued our work on the relationship between voltage and CdS thickness with CdTe cels; the relationship between fill-factor of a cell or module and sheet resistance, geometry, current, and the J_{SC}/V_{OC} ratio; and the effects of local shunts on cell performance. Since the funding of the AVA incubator project took effect, I have shifted our work on CSU and AVA CdTe cells, and the reporting of those results, to the incubator project.

Presentations. I made four presentations abroad during December and January. My invited talk at PVSEC-17 in Fukuoka, Japan, was entitled, "Voltage Limitations for CIGS and CdTe Solar Cells." The following week, I spoke at the Industrial Science and Technology Institute (ITRI) in Hsinshu, Taiwan, on "Device Physics of Thin-Film Solar Cells," and the next day to the Taiwan Photovoltaic Association on "Thin-Film Solar Cells: The Potential and the Challenge." On a separate trip to Bangalore, India, in January my talk at the J. Nehru Research Center, associated with the Indian Institute of Technology, was "Materials Studies in Physics at CSU with Special Emphasis on Thin-Film Solar Cells." None of my foreign travel expenses were charged to NREL.

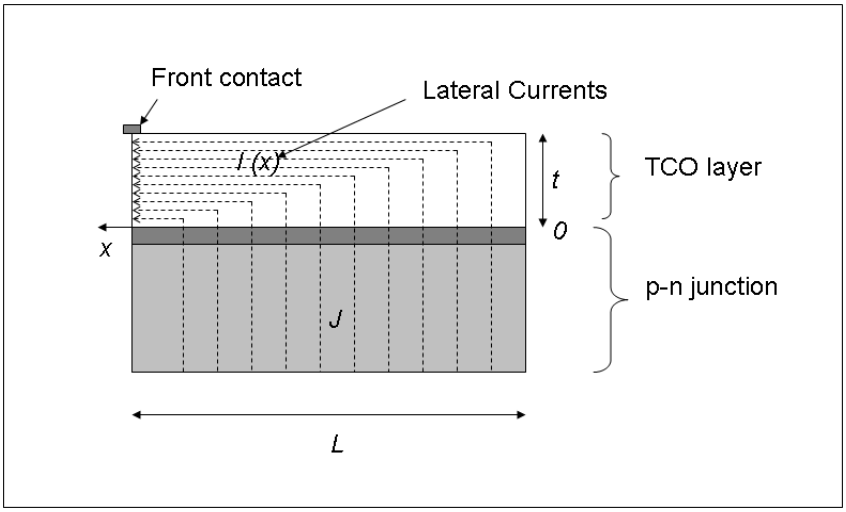
CdTe Cells with Thin CdS. Students Alan Davies and Lei Chen have explored CdTe cells with progressively thinner CdS buffers both experimentally and with

numerical simulations. The common experimental observations are that current increases track optical-absorption decreases as CdS is thinned and that voltage, which is relatively independent of thickness above 50 nm, decreases sharply below an onset thickness.

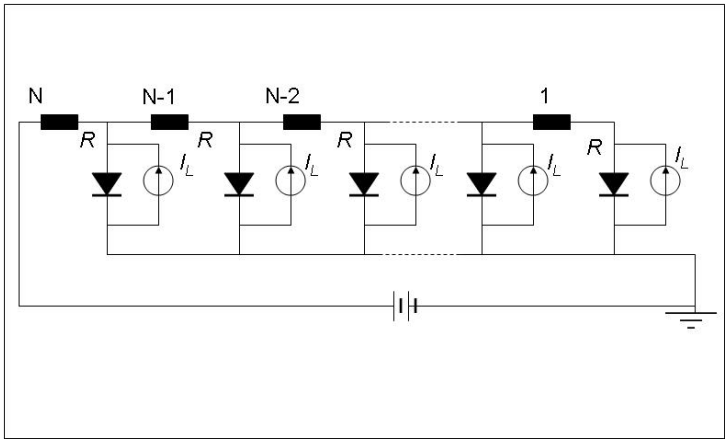
We refer to our model of the voltage decrease as the coverage model. It simply says that if there is continuous CdS coverage, the entire junction is CdS/CdTe, and the voltage is relatively high and constant with CdS thickness. Below a certain thickness, however, the coverage is no longer complete, and the voltage decreases sharply. A straightforward calculation shows that only a small area of CdTe in direct contact with the SnO_2 transparent-conductor layer will dominate the overall cell voltage. In the limit of zero-thickness CdS, the voltage is simply that of a SnO_2/CdTe solar cell. When there is an intermediate CdS thickness, there is a mix of CdS/CdTe and SnO_2/CdTe junctions, which can be seen dramatically in an LBIC map taken under bias voltage.

The expected voltage and efficiency of a SnO_2/CdTe solar cell was calculated as a function of the conduction-band offset (CBO) and the interfacial recombination velocity. They were found to be relatively insensitive to the recombination velocity and to decrease as the CBO is made increasingly cliff-like. Depending on which CBO is assumed, a voltage reduction of 200-400 mV, similar to that seen experimentally, would be expected. Independent of the SnO_2/CdTe CBO, the inclusion of a full-coverage CdS layer should produce a voltage of 800 mV or greater.

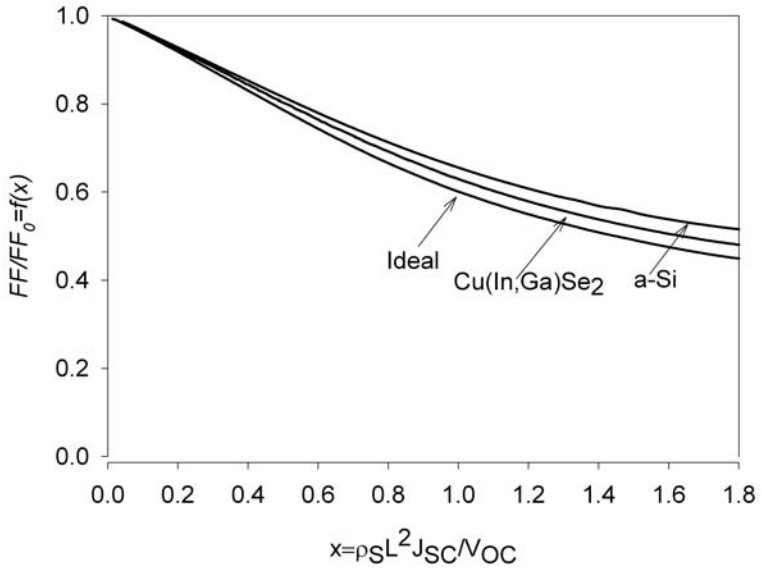
Cell and Module Fill-Factor. Galym Koishiyev has made calculations of the current-voltage curves for the geometry common to gridless CIGS and CdTe modules where the lateral voltage drop across the TCO layer is large enough that the single-parameter series-resistance correction to the diode equation fails. The geometry for the calculations is shown below:



The calculations were done with PSpice, assuming a parallel array of small cells connected by resistances R to simulate the lateral resistance of the TCO:



Of particular interest is how the fill-factor of a module-geometry cell will change with TCO sheet resistance ρ_S and length L of the cell. Results for three cases, with parameters corresponding to typical amorphous silicon cells, high-quality CIGS, and ideal solar cell are shown below. When the fill-factor is compared to that in the absence of TCO resistance and plotted against the dimensionless quantity $x=\rho_S L^2 J_{SC}/V_{OC}$, a nearly universal relationship is seen (a similar calculation is found in the book by Fahrenbruch and Bube).



The value of x will be 0.5 or less for most practical situations. In this range the fill-factor reduction will be nearly linear with sheet resistance, the square of cell length, and the J_{SC}/V_{OC} ratio. It will be slightly larger when a cell is closer to being ideal.

Effect of Shunts. Galym is also calculating the effect of local shunts on the conductance (inverse shunt resistance), and hence the fill-factor of the cell. It appears that the effect on fill-factor is primarily a function only of the local conductance (in mS), and it is little affected by the size the shunt, its position relative to the contacts, or the sheet resistance of the TCO used.

Collaborative Work. Measurement and analysis of both selenide and sulfide cells made at FSEC will be reported in two joint posters at the May PVSC meeting. Similarly, measurement and analysis of CdS/CdTe cells made with a large range of CdS thicknesses at the University of Toledo will be presented as a joint poster. Finally, we have begun a collaboration to measure and analyze a number of cells made at SoloPower.

Sincerely,

James R. Sites
Professor

Cc: NREL Subcontracts
CSU Office of Sponsored Programs